THE CO-OPERATION OF SCIENCE AND INDUSTRY

S. ROY ILLINGWORTH

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THE CO-OPERATION OF SCIENCE AND INDUSTRY

BY

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With Foreword by

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"WAKE UP, ENGLAND"

A PLEA FOR THE CLOSER UNION OF INDUSTRY
AND APPLIED SCIENCE

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FOREWORD

THE importance of scientific guidance in manufacturing operations is now so generally recognised that at first sight the need for such a book as that which Mr. Illingworth has written may be questioned, but this is merely a superficial view, and a critical consideration of the subject will show that the need is as great as it has ever been.

The truth is that, whilst the great majority of the directors of industrial establishments in this country have been forced to admit the value of the help which Science can render, they have not advanced beyond the stage of accepting this view in the abstract, and are apparently far from applying it in practice. The excuses offered for this illogical attitude are various. It is suggested that procedure which may be attended with admirable results abroad may not be beneficial under our insular conditions; or that the prospective gain is not commensurate with the certain cost; or that men of the requisite scientific attainments are inherently and necessarily unpractical.

Meanwhile, international competition in the markets of the world grows keener year by year, and British supremacy in those industries in which we have hitherto excelled is endangered by the steady advances of more enlightened nations. To meet this growing competition the principle already accepted grudgingly and in the abstract must receive whole-hearted application, and any existing grounds for procrastination must be removed. If the manner in which our factories are conducted does not readily lend itself to scientific control it should be altered; if there is apprehension that the cost may be in excess of the gain, confidence should be given by the study of the results which the author cites; and if the right men for the work cannot as yet be found a supply must be created.

As matters stand, there is no certain demand for scientific services, and, therefore, as the author points out, no inducement to scientific men to become qualified for such positions. It is the aim of the author to put an end to this deadlock, and his book may be commended as a convincing demonstration of the national importance of the subject on which he has written.

In publishing this book the well-known firm whose name it bears have given further proof of their interest in technology, and in presenting his thesis in a form which invites perusal have effectively supported the author's efforts.

BOVERTON REDWOOD.

Jan. 7, 1914.

PREFACE

THE main issues of the vital question of Science and its relationship to Industry are closely interwoven with our educational policy. Industry must take an important part in the shaping of this policy, for in order that we shall obtain the maximum return from education, we must have the co-operation of our commercial men; especially is this co-operation needed if we are to gain the best results from our higher education in Science. It is essential to our industrial welfare that we pay more attention to the scientific control and expansion of our factories, and spare no energy in bringing about that state of affairs in which Science and Industry work hand in hand. A number of pronouncements upon this problem have been made from time to time by people of wide reputation, but in the majority of cases their remarks have been delivered before various learned societies, and apart from a brief report in the Press, they have not come to the notice of the general public. This little book has therefore been written to try to bring the salient points of the question of Science and its relationship to Industry to the notice of the commercial man, well knowing that he is ever ready to consider any project for increasing his profits. Science contends she can help Industry along genuine business lines, which claim I hope the following pages will establish.

I am indebted to my friend Dr. Manfred Ragg for his great kindness in reading through the manuscript, and for several suggestions that I have incorporated in the following pages. I also wish to tender my best thanks to Messrs. Chas. Griffin for the kindness and many facilities they have extended to me in the preparation of this book.

S. R. ILLINGWORTH.

London House,
S. Woodford, N.E.
Jan. 1914.

CHAPTER I

① SCIENCE in its broadest sense may be defined as exact knowledge. The significance of the use of the word "exact" cannot be too firmly impressed upon the mind of the non-scientific person, for upon a true appreciation of the aims and scope of Science depends the answer to the question as to what part we should expect the scientist to play in industrial concerns. Only the study of Science itself can bring home to one the distinction that should be made between Knowledge in its ordinary sense and Science (as defined above), but perhaps a sketch of the growth of a "science" out of the "knowledge" of the ancients may assist the reader to grasp the distinction, and for this purpose we may select the science of Chemistry and trace its evolution from the Alchemy of the past, but it should be distinctly understood that the same reasoning applies to all branches of Science.

The pioneers of Chemistry were the old sages and philosophers known as the Alchemists. Their labours were devoted to the study of the properties and transmutations of substances of common occurrence. This work they carried on incidentally with attempts to discover the Philosopher's Stone, and the Elixir Vitæ, that would enable them to get rich quickly, and then live to enjoy their wealth without suffering from gout or from an impaired digestion. Their work was haphazard, and every substance was treated in an individual manner. They amassed many facts—that is, they gained knowledge—but they made few attempts to explain their observations, nor were they able to fathom the forces at play causing the observed changes. This early school of Chemists gave way to another one, to whom explanation of phenomena was the essential feature, but they erred in being too fond of theorising on grounds hardly supported by experimental evidence. It was not until the end of the eighteenth century that Chemistry became a Science. This was due to the application of methods of measurement to experimental work, which, in conjunction with the correlation of the observed facts, has brought to light the truth that all chemical phenomena can be grouped into a definite system. The development of this essentially scientific method of investigation has laid bare the foundation of Chemistry upon which succeeding generations of Chemists have reared the noble edifice of the modern Science. The fundamental object in rearing this building has been, and still is, carefully to determine the relationship existing between any individual part and the rest of the structure, and to weave cause and effect into an orderly chain. So systematically and accurately has this edifice been built that phenomena can now be explained and forecast without recourse to laborious experiment. It is this marshalling of facts, this measurement and the resulting deductions, that distinguish Science from Knowledge, as we ordinarily understand that term. The transcendental importance of laws and of correlated knowledge to a science may be compared to the means of communication existing in any country to a traveller therein. For instance, the traveller may wish to travel from one place to another, but knows not what route to take, what the proposed destination is like, where to stay, &c. He is possessed of no exact knowledge, but by consulting the map of the country, making inquiries of an expert in travel, &c., he is able to accomplish his purpose with the best results. The traveller in the land of Science is in an analogous position. Here, for instance, in the country of Chemistry we find the expert to guide our operations is the Chemist. The map of the whole community of substances in Nature is set out in his mind; a map built up by studying the work of the Chemists of the past. He knows the intimate relationships of substances, their nature and their use. He can advise the best means of passing from one to another, when to perform the operations, and how most easily to perform them. Summing up, we may say Science is that highest form of Knowledge in which the relationship of all known facts has been ascertained, traced, and reduced to laws, these laws enabling the scientist to forecast the action of substances, forces, &c., upon other substances and forces. Still further, they enable him to utilise forces and substances to produce desired effects.

The Scientist is naturally well versed in these laws, laws that fulfil both quantitative and qualitative functions. His mental attitude to the hundred and one forms of matter is orderly and logical. His brain is like the cinematograph film; one by one he has stored therein the various impressions that, following one another, produce the whole sequence of events in any cycle of operations. At any time he can begin to think from a particular point in the cycle and follow up any observed phenomena to their logical conclusion. Continuing the simile of the railway service, we may compare the true scientific brain to the railway time-table. By consulting the latter anyone can ascertain when to start from a certain place upon a particular journey. In the same way the Scientist, by virtue of his orderly intellect, knows when and how to put into operation a certain process. This orderliness and breadth of view, which can only be attained by scientific study, cannot be too firmly impressed upon the non-scientific mind. It permits of the Scientist coming to valid conclusions, or, as some may say, "prophesying" the results to be obtained in any cycle of operations. The Scientist has brought to light and studied the effects of the forces around him. He has come to understand all kinds of matter and the methods of influencing them. In a word, he studies all phases, forces, and materials of Nature.

Industry, on the other hand, is the art of producing from one form of substance other forms for which there is a demand. Under existing circumstances this production takes place in such a manner that the maximum efficiency is rarely, if ever, attained. Maximum efficiency requires that in the process of manufacture the least cost shall be incurred and the best article commensurate with cost produced. To dwell on the aims of Industry would be futile. Suffice it to say that its fundamental activity is concerned with the changing of the forms of matter for pecuniary gain. Does this not appear to be closely interwoven with the aims of Chemistry? What answer should be given to the query, "Have Science and Industry any common ground upon which the two could work together for mutual benefit?"

We have seen in the earlier paragraphs that the modern Chemist is concerned with the methods of changing one form of substance into another. Remember he is not concerned with these changes in the "Cookery Book" or empirical manner; his sole aim is not to add so much of this, a drop of that, heat for so long, and attain the desired result. His concern in the operations involved is far deeper. He comprehends the forces underlying these changes, the machine, so to speak, determining the transmutations. His position towards matter is analogous to that of the medical man towards the human body. The Chemist can "prescribe" for matter, remedy many defects in its nature, and determine the changes it can undergo. He is not a magician or a quack, but can use his scientific *knowledge*,

knowledge built up by the best brains of the past, to cause and direct the production of one form of matter from another. Here lies the common ground upon which the Chemist and the manufacturer can meet and *co-operate.* The manufacturer should be conversant with Science, he should invoke its aid to advance his interests. In England at the present day the co-operation between the manufacturer and the Chemist is fitful and uncertain. Our industrial methods are frequently obsolete; they undergo little or no improvement, and we have very few Chemists engaged upon Research Work. Many of the processes of manufacture conducted in this country are wholly empirical, and they are not under the control of people who comprehend the principles governing the manufacturing operations. Industry, like everything else, must improve along evolutionary lines. It is imperative for our national industrial stability that we be careful to see we are not left behind in this evolution, wherein the law of the survival of the fittest will operate. In naval and military matters we are jealous of foreign countries and of the progress they make. Do we exercise the same degree of jealousy or expend the same amount of energy in advancing our methods of production? We do not. We are behind our foreign competitors, and the longer we are content to remain as we are, the harder it will be to make up leeway. In our days all improvements and new inventions emanate from abroad. Many of the industries that arose out of the research and scientific attainment of our own countrymen have passed into foreign hands. The reason is evident: in these countries Science and Industry work hand in hand. Our manufacturers are already feeling the effects of this foreign competition. Articles in the manufacture of which they held pride of place are being turned out abroad superior in quality to those of British make. Competition is becoming keener year by year, and fractional parts of a penny saved in the cost of production will become increasingly important. Waste in any process must be cut down, and from it new commodities must be evolved. How can this be done? By following on the lines of our rivals and bringing Science more fully into our factories. In a word, Science and Industry must combine. Proof of the truth of the above statements and of the urgency of the need of such Combination and Co-operation will be given in subsequent chapters.

CHAPTER II

THE benefits that Science has given to the world are manifold. Volumes would be required to do anything like justice to such a colossal subject as the effect of Science upon civilisation, and its history would constitute one of the most fascinating romances ever written.

Cast your thoughts back to the state of things existing at the close of the eighteenth century, and contrast it with the present state of affairs. Instead of having gone back a hundred years, you will feel that by contrast you have gone back a thousand years and more. It is hard to single out any prominent innovation in the period previous to 1800, for what progress was made during this time was slow and the result of the accumulation of years. What a difference is found in reviewing the period from 1800 onwards. Throughout this time epoch-making inventions flash out as if from nowhere, improvement follows improvement with bewildering rapidity, and one wonders what it all means. The reason for this marked difference in the periods mentioned is, however, not hard to find, for the dawn of the nineteenth century witnessed the birth of Science as we now understand the meaning of this word. It was this new force, this new outlook on our surroundings, that has brought about the countless changes seen in all walks of life. What do we find in briefly surveying the last century? We find new colours flashing into view. Communication in every form is more intimate, distance appears to vanish, our methods of transit becoming weird and superhuman. Of a truth Science has put a girdle round the earth in forty minutes. Our homes are better lighted and our streets are no longer the nightly resort of footpads, for Science in bestowing the boon of efficient lighting and rapid communication has rendered the task of the evil-doer far more difficult. Science has improved our health through the progress of medicine and hygiene. Science, like a magician's wand, has transformed our very existence, our diet, and our habits.

The triumph of Science entirely surrounds us in our everyday life, and her productions have become such deep-rooted necessities that we hardly realise the extent of the stupendous debt we owe to our ever-generous benefactor.

Business could never have expanded to its present size had not Science placed a thousand and one facilities in the hands of Commerce. Those business people who decry Science as a useless factor in Commerce have only to reflect for a moment to find their telephones, telegrams, means of rapid transit on land and by sea, cheap stationery, lighting, in fact their very existence is the outcome of Science! Without it, it would be impossible to carry on a minute fraction of the world's present transactions. Imagine trying to conduct business if letters from London still took three weeks to reach Glasgow, if goods took months and months to reach America, and if there were no direct communication between inland towns, let alone between continents. Now it is possible to cable to nearly any part of the world and to receive a reply the same day. Distance has vanished in comparison with the past, and time has been prolonged, because so much more can now be done in a given time than could be done even a decade ago. And it is Science that has to be thanked for it all, since every one of these time-saving, labour-saving devices, means of rapid communication and transport, &c., is the culmination of ceaseless endeavours of generations of Scientists. They are not the outcome of haphazard leaps into the dark and "lucky shots." They have arisen by the subtle method of experiment and theory, theory and experiment, of which none but those of scientific training are capable. That academic refinement so scoffed at by certain ignorant people is the very essence of progress and of the achievements of modern civilisation. The most certain way of expanding our manufacturing activities by producing new products, improving existing ones, and attaining greater efficiency in our factories, is to realise this dependence of Industry on Science, and to employ the technologist to a larger extent in the factory.

The Scientist is for ever trying to harness the forces and develop the materials of Nature for man's use. Let us trace the fascinating steps by which the Chemist has built up new industries, and see how he has seized upon the waste products arising at one stage to build up yet newer and more lucrative processes. To illustrate this process of what may be termed the evolutionary uses of Nature's storehouse, we will turn our attention to coal, and see what part this commodity plays in Industry.

Coal, as everyone knows, is the product of the fossilised remains of forests that grew ages ago. We in Great Britain are almost entirely dependent upon it for our national welfare, and we should look to it that we make the best use of our present supply and use every endeavour to develop our coal-fields. The first use to which coal was applied was that of supplying heat for domestic purposes. Coal as a domestic fuel was employed for centuries before its utility in manufacturing processes was discovered. Subsequently it was productively employed, first in the raw state, and later in the form of coke, in the metallurgical industries, and particularly for the manufacture of iron. Apart from these applications, the use of coal as a raw material proper was not introduced on an industrial scale before the earlier part of last century, when it was employed in the production of illuminating gas. The products arising from the distillation of coal for this purpose are of three kinds: (*a*) the gaseous products, (*b*) the liquid products, consisting of coal tar and ammonia liquor, and (*c*) the residue, consisting of coke. For many years after the birth of this industry the only useful products arising from it were the gas and the coke. The liquid products were regarded as a necessary evil of the process for which no commercial use could be found. Through the discoveries arising from the patient endeavours of many chemists these liquors, at one time regarded as the bugbear of the industry, are now looked upon as most valuable products. The coal-tar liquors consist of a complex mixture of what are termed hydrocarbons, accompanied by compounds belonging to the same chemical class as carbolic acid. The tar distillers separate this complex into its constituents, and produce the hydrocarbons benzol, toluol, xylols, naphthalene, &c., as well as the carbolic acids, creosote, pitch, &c. Each of these products is much sought after in commerce, for chemical research has found for each and all of them a lucrative commercial use. Thus early in this brief survey of the industrial uses of coal do we come across examples of how Science forces out new shoots from the tree of industry, and we shall see how these new shoots rapidly develop into strong branches, from which Science forces out yet again fresh shoots. Let us turn our attention to some of these coal-tar products and see to what uses they are applied.

Has the reader ever marvelled at the endless range of shades and colours that confronts him in, for example, the drapery stores? Has he ever chanced to inquire into their origin? What a romance, what a triumph of Science is portrayed by this endless range of colour.

Years ago who would have dreamt that such colours would arise from that noxious oily liquid resulting from the manufacture of gas? To read the romance of the coal-tar dyes must bring a blush of shame to the cheeks of all Englishmen, for they will realise what the conservative prejudice of our forefathers has lost to this country. The way to this vast and lucrative industry of the manufacture of dyes from coal tar was shown by the researches of our fellow-countryman the late Sir W. Perkin. Alas! Englishmen are not reaping the rich harvest of this industry, for the mistrust of Science so typical of many of our commercial men would not allow of their supporting the infant industry that has now grown to such gigantic proportions under the fostering scientific care of Germany. To-day practically all dyes are built up from coal-tar products by chemical processes. One by one the natural colours have been imitated, and dyes of vegetable and animal origin fallen into desuetude. This is not all, for slowly but surely the Chemist has built up the complex science of the dye-stuffs that permit of his producing the most subtle differences in shade and a range of colour undreamt of in the days of natural dye-stuffs.

The value of the imports of coal-tar dyes into this country has steadily risen from £708,797 in 1899 to £1,818,575 in 1912, the bulk of these dyes being derived from Germany. On the other hand, the exports, which presumably refer to home-made products, have remained almost stationary, and amounted in 1912 to a value of £204,475.

It should not, however, be forgotten that millions of pounds have been expended in experiment; failures there have been, but the Germans realise the value of Science, and to them these failures have been but stepping-stones to new industries; their faith never falters. This faith in Science has given them the monopoly of the dyestuff industry, and a proud position in the commercial markets of the world. What would some of our commercial men think of an expenditure of three-quarters of a million pounds in experiment? One feels that many of them would have abandoned the endeavour long before such a sum had been spent. Not so the great German firm of Baeyer, who spent this amount before they were able to manufacture indigo on a commercial scale. Their process turned naphthalene, once a waste product and the bugbear of the tar distillers, into a valuable raw material. This discovery affected our Indian Empire very severely, for prior to it nearly all indigo came from the indigo plantations in Bengal, but now this natural industry is practically dead, and the great bulk of indigo comes from Germany. Whilst speaking about indigo one cannot help mentioning an example of ignorant prejudice exhibited by some of our dyers. These gentlemen, when the synthetic product was first introduced, did not like to use it because the dye liquors made from it lacked a smell peculiar to the natural variety. They did not realise that this artificial variety was constant in composition and, compared with the variable natural product, gave more certain results. The coal-tar dyes are not the only products obtained from the liquid products derived from the distillation of coal, for each and all of the products have other uses. The tar acids are extensively used as disinfectants. Carbolic acid is the parent substance of a whole host of drugs, food preservatives, and medicines. Salicylic acid, salol, and aspirin, frequently used for the last purpose, have as their parent this coal-tar product. Creosote is used extensively as a timber preserver, and prolongs the life of many structures. Pitch, the product remaining after removal of the hydrocarbons and tar acids, has a host of uses, such as making damp-proof walls, asphalt, &c. Tar finds many applications, and is especially used nowadays for making dustless roads. Perhaps in the future these coal-tar products will play a great part in our power supply, for already they are used to some extent as a liquid fuel, and such uses will no doubt increase.

Thus far we have dealt in a very cursory manner with the oily portion of the gas liquors. The other portion, known as the ammonia liquors, is also a very valuable product. The main constituent of this liquid is, as its name implies, ammonia. This body is liberated from it and converted in various salts of ammonium. Chief amongst these is ammonium sulphate, which is extensively used as a fertiliser, and hence we reap material benefit from these liquors in the shape of greater crops and a better food supply. Not only does our food supply benefit in this manner, but upon the use of ammonia is based the principle of cold storage. This cold storage not only permits of fresher food, but also allows this country to draw its food supplies from far-distant lands, and to enjoy fruits and perishable goods not thought of years ago. The benefits of cold storage have been derived from the combined efforts of the chemist and of the engineer, who have jointly perfected a machine which causes ammonia to evaporate at one point with the production of great cold, and to condense back at another point to its former state in readiness for passing through the cycle of changes once again. It is by this evaporation of ammonia that most of the ice to-day is made. Like many other processes, the process of cold storage is changing; solid carbon dioxide is used on board ship in place of ammonia, and a further development is the use of formalin as an antiseptic preservative, but in whatever direction change ensues, Science shows the way.

The gaseous products of the gas industry have engaged the attention of the Scientist, for he is never content, but is for ever striving after improvement. Who to-day would tolerate the evil-smelling gas of the past? This evil smell was due to the presence of sulphur compounds, and the Chemist devised methods to remove them. This removal was effected by passing the gas through large chambers filled with oxide of iron or lime. Revivification of the iron oxide by exposure to air and repeated use of the revivified material results in it ultimately retaining upwards of fifty per cent. of its weight of sulphur. The material thus produced is now the source from which a considerable amount of our sulphuric acid is derived. This example shows how the Scientist tackles his problems and converts a defect into a blessing. There are yet further valuable products removed from the coal gas, namely, the poisonous cyanogen bodies it contains. Their removal is effected by chemical means whereby the cyanogen is recovered as potassium cyanide and utilised for the extraction of gold from low-grade quartz. This does not by any means exhaust the history of the results of Science applied to coal gas. There is, for instance, another important improvement to be mentioned, the incandescent mantle. Contrast the old form of light with that we now enjoy, and remember that it is Von Welsbach, the Austrian Scientist, who has to be thanked for the improvement. This innovation caused Scientists to turn their attention to what they termed the rare earths, and to open up a commercial use for them.

The above paragraphs have been written to show how Science has affected what may be termed the "coal" industry. Even this brief survey must cause one to realise the far-reaching effects of Applied Science upon industrial operations and commercial progress.

It should be remembered that this is but one page from the voluminous history that could be written on the achievements of Applied Science. Does it or does it not suggest sufficient proof of the statement that Science can help Industry, and should be working in co-operation with her? It should be remembered, too, that many of these innovations and new industries arose in the first place from the labours of the "academic" men—that is, of men not engaged in actual commercial work, but in the teaching of Science. If so much has been accomplished along such lines in the past, how much greater improvement can we expect if every factory had its scientific expert, ready to tackle any problem, and to seize upon the chance of utilising waste material? Everything points to much good accruing. Chances of utilising waste may have come, but they have not always materialised because the individual to whom the opportunity occurred has not had sufficient scientific knowledge of his subject or breadth of view to realise the importance of the occurrence.

Chance has played a large part in the discovery of new processes and new industries, but always in conjunction with the scientific development of the opportunity offered. Thus when the late Sir William Perkin discovered the first coal-tar dyes, he was really working on the constitution of quinine, but his investigation took an unexpected turn, which he seized upon, investigated, and developed, thus initiating the industry of the coal-tar dyes. Again, the commercial realisation of the manufacture of indigo arose from the breaking of a thermometer. One stage in the process under investigation demanded the oxidation of naphthalene to phthalic acid. It had been discovered that sulphuric acid would effect the oxidation, but only to a limited extent. When the thermometer broke it was found that the process had been completed. Here was the chance, and the scientists conducting the experiment made use of it, for they elucidated the reason for the complete oxidation, and found that the mercury from the thermometer was the cause.

Chance alone is of no use, however; what is needed is the man on the spot who can avail himself of it. The Scientist is the man required; his training and consequent elasticity of mind never allow him to let anything escape unnoticed, uninvestigated. Just as a blind man could not be expected to discover a goldfield, even if he were sitting down on an outcrop of gold-bearing quartz, neither can a "rule-of-thumb" man be expected to realise the possibilities of some occurrence in the factory. What is needed is the man possessed of scientific insight. Other countries employ such men in their works and reap the benefit. We are behind and must make up the leeway. Let us consider first what our foreign rivals are doing with their Scientists.

CHAPTER III

THE Englishman was the pioneer in Industry, and for many years enjoyed the advantage of his early start. The world was his market, and English goods went everywhere without commercial opposition. Time has changed this state of affairs, and the English manufacturer has now to compete with those of other countries both in the home and in the foreign markets. Already we hear the cry of ruined industries, and some people are too prone to decry us as a "scrap-heap" nation. Such persons should view this question of foreign competition from another standpoint, namely, by comparing the methods of production at home with those in vogue in other countries.

The last chapter gave a brief outline of the colossal extent to which the manufacture of dyestuffs has grown in Germany. That this growth is due to the application of Science to Industry is beyond question. A visit to one of these large dye factories would open the eyes of the man who decries Applied Science. On such a visit he would meet the Scientist at every turn. In the laboratories he would find the Chemist engaged in various capacities. Men of University training would be found applying their knowledge to the control of works processes. Such men would be found carrying out analyses of the raw materials, checking at every stage the multiplicity of the works operations, and finally making sure that the finished product was up to standard. Not only would he find the University man acting as "policeman" to the works, and keeping it on its best behaviour, but he would find him *acting* in a *directive capacity* (as a *research chemist*), investigating methods, producing new products, improving old processes, and cutting down the cost of production. It is this application of Science that has done so much towards building up the present industrial position of Germany. This probing into the fundamental principles of a process, whereby a thorough working knowledge is attained, is the secret of all innovations. Working along these lines, failures in manufacture are rare, spoilt batches to be sold at a loss are few. Customers' complaints are seldom heard, for every batch of goods is tested before dispatch, with the resulting boon of uniformity in quality, and uniformity in the cost of production. In

Germany everything is manufactured under the eagle eyes of trained Scientists; works managers, and often works foremen, are University, Polytechnic, or High School men. Nothing happens in the works that escapes attention; failures, when they do occur, are investigated, improvements made, and a recurrence of the trouble prevented. This one instance is typical of the industrial methods of Germany. In one of her large dye-works one hundred and fifty trained Scientists are employed, all of them University men. The members of this staff engaged upon research work turn out about three hundred new dyes a year, only a fraction of which become commercial articles. Yet this procedure pays, and pays well. Waste material in Germany is rare compared with this country, for everything is experimented upon with a view to finding a commercial outlet for it. An object-lesson for the Englishman is furnished by the large quantity of old "tin-cans" imported into Germany from this country. In this country they are regarded as waste, and disposed of, for the most part, for next to nothing. To the German they are the raw material of an industry. Stripped of solder and paint, these waste "tins" are so treated that the tin coating is converted into tin salts, and the residual iron is utilised as scrap in steel works. These tin salts are in all probability exported back to our dyers, and used in conjunction with Continental-made dyes to produce, maybe, the parti-coloured buntng that the loyal Englishman proudly displays in honour of some important occasion. Another example reflecting the different attitude of the English manufacturer compared with that of his Continental rival is to be found in the case of sugar refining. An important refinery in this country is content to turn its residues of molasses into the sewer. Not so the Continental firms: they convert it into potassium carbonate and betaine of pharmaceutical value and into cyanides. These cyanides, much used in gold extraction, are also extracted from the "schlempe" of the Continental brewer, whereas our brewers pay no heed to this method of utilising their waste.

Space forbids further mention of the scientific developments that have led to industrial innovations. "Made in Germany" is like a red rag to a bull with some Englishmen, but if they would probe deeper into the reasons for the monopoly, they would find the "tag" should read "Made by Scientific Germany."

Let us see what the U.S.A. are doing along scientific lines. We find the Americans are invoking the aid of Science in every possible way; more especially do we find Science applied to the development of her national resources. State and national bureaux have been established for every conceivable object, from Agriculture to Emigration. A brief description of the methods of the Agricultural Bureau will give some idea of the far-reaching influence of these institutions. In the first place, there is the National Bureau in Washington, which is the headquarters of the large staff engaged on the development of the whole agricultural area of the States. In addition to this central organisation many of the individual States have their own Agricultural Colleges that combine the function of training agricultural experts with that of advisers to the local farmers. These institutions are the guiding hand in agricultural affairs; to them the farmer turns in time of difficulty. Thus he may send his soil to have it analysed and reported upon. He will be given information as to what manures to use in its improvement, for what crops it is suitable, and he will even be supplied with the best seed for these crops. He can always turn to these institutions in cases of blight or failure of crops, well knowing that he will receive the best possible advice. In some cases, if needs be, an expert will be sent to his farm to investigate the trouble on the spot. That good has attended this comprehensive scheme goes without saying. For instance, at one time the yield of wheat per acre of certain districts in California had fallen very much below the average. The Berkeley University took the matter in hand, and in four years the yield was increased tenfold. Another proof of the activity of this University is furnished by its methods of taking, so to speak, the college to the farmer's doorstep. Every year the staff tours the State in a train specially equipped with lecture rooms, demonstration rooms, a museum, &c., making stops *en route* in order to deliver lectures and to exhibit the latest developments in farm appliances.

Although the organisation of expert advice and assistance to farmers and other agriculturalists is not organised in this country to the extent that it is in America, there are a good many experimental stations and colleges where advice can be obtained and analyses supplied at exceedingly reasonable rates. In this connexion, the experimental stations established at Rothamsted by Sir J. B. Lawes and at Woburn by the Royal Agricultural Society may be mentioned. In the past few years we have seen the establishment of a special Parliamentary Grant for Agricultural Development, part of which grant is devoted to the training of a staff of advisers in agricultural matters. Let us hope this is the commencement of a vast scheme to establish our industries upon a sound scientific basis.

To-day all new processes, inventions, and developments emanate from abroad. In the past we could point to many epoch-making inventions as of solely British origin, but what outstanding innovations of the last twenty years lie to our credit? Motor-cars, wireless telegraphy, aeroplanes, the Diesel type of internal-combustion engine, &c., all have their origin abroad. Turn where you will, look into the running of any concern you like, and you will find that the foreign rivals of this country are ahead of us in applying Science to Industry. The originators of our industries were men of scientific outlook, and never ceased experimenting to perfect their processes. For many years these industries had no serious foreign competition, but now all is changed, and we must alter our methods to cope with the change.

Contrast the current methods of most of our industries with those in operation in Germany, Austria, U.S.A., &c. On the one hand we have empiricism, rule of thumb, and a conservative contentment with the old order of things; on the other we have ceaseless endeavour along scientific lines to produce improvement and greater efficiency. We know the English manufacturer desires improvement, but in many cases he goes to work along the lines of trial and error on a large scale. His attempts at improvement are often leaps into the dark, spasmodic and unscientific. In many cases these attempts have only been made under the stimulus of the loss of trade consequent upon the appearance on the market of an article superior to his own. There is little endeavour to get ahead and *keep there* by means of systematic research work. We also are behind the times in the utilisation of the routine man. Works processes are not adequately checked, and finished products are not regularly maintained at a uniform quality. As one who has had to deal with the supply of goods to conform with a rigid specification, the author can speak from experience. The tender samples submitted from a large number of firms, and professing to be of definite quality, are a profound object-lesson. Some of these samples would be much above the requirements, others would be below, a very few would conform closely to specification. Then, again, the deliveries will vary greatly. One delivery would be just right, another would be too high, and one day a supply would fall below the limits. One could realise the empirical methods of manufacture in operation and the lack of scientific control. How much a Chemist would save these firms it is impossible to say, but the variations in quantity of an expensive ingredient must represent considerable variation in profit.

Adulteration is very rife to-day. Candidly, I believe there is more opportunity in this country for a Chemist to " do " the manufacturer than there is for him to assist him. This represents laxity in testing on the manufacturer's part, and until he alters his ways he will be " done."

The business man has not the time to occupy himself with scientific problems, nor has he the knowledge to solve them, so naturally he cannot appreciate the usefulness of Science unless that usefulness is drilled into him. It is for the Scientist to emphasise this aspect of his subject to the business man, as there is no doubt the latter will, in the majority of cases, lend a willing ear to any scheme for enlarging his profits. Of course there are some who will not, because they still regard Science as a harmless pastime for old men and young boys, a " hobby " that serves no useful purpose. The two extremes in the rival camps—that is, the Scientist with a lofty contempt for commercialism, and the business man with a bigoted and ignorant prejudice against the vitalising effects of Science—should be eradicated from our midst. Science and Industry must co-operate for our national good. There are faint signs of a *rapprochement* to-day, but it must be galvanised into a certainty. The co-operation must be wholehearted; nice mutual-admiration after-dinner speeches in evening dress can be dispensed with. We must have the "shirt-sleeve" attitude of the Briton *bent on improvement and development.* Then we shall find that Applied Science, directed into proper channels and unhampered by prejudice, is the nation's strongest weapon to resist the keen competition of our foreign rivals.

Let us see in broad outline to what uses the Scientist could be put, and when we have realised this aspect of the question, we must study the type of man needed, and how best to train him.

CHAPTER IV

IN the previous chapters an endeavour has been made to show that in this country more Chemists should be employed in Industry. To many people it may appear that the only industries in which the Chemist would find scope for his knowledge are those engaged upon what may be termed true chemical operations, such as sulphuric acid manufacture, soap-making, explosives, the production of dye-wares, &c. True, it is in such industries as these that one would expect to find the Chemist, but my contention is that every factory, mill, or foundry engaged on the actual manufacture of articles, and hence using a hundred and one different accessary substances, should, simply for its own protection, have its chemical laboratory. To attempt to give proof of this contention in the case of every type of manufacture would be impossible, but I trust the few examples given below will cause the reader to reflect on his own business, and perhaps find there is need for the Scientists therein.

The chemical department of a factory must act in an advisory capacity to the business side. In addition it must control, direct, and develop works operations. The head of the factory must be a technologist, a man possessed of full scientific knowledge of all allied subjects, and also of factory experience. The regulations governing the Austrian factories stipulate that the heads of such concerns must be trained, fully qualified technologists, just as in the case of our coal-mines the managers must have certain qualifications laid down by Act of Parliament. With these instances in mind, comment on the technologist being head of our factories is unnecessary. My business readers must not think I want the laboratory to be a dictatorial department; rather I look upon it as a department just as essential to a works as its sales department, one dealing solely with its own duties yet working in sympathy with the whole concern. What the actual duties of this department will be will depend naturally upon the industry involved, but broadly speaking they may be classed as under:

(*a*) To control works processes by periodical tests.

(*b*) To report upon the suitability of material for the works' purposes to the buyers, &c.

(*c*) To standardise all products of manufacture.

(*d*) To initiate improvements and increase the efficiency of the industry.

(*e*) To be alert to match any article, &c.

To carry out the duties enumerated above, the department would have to deal with two classes of work, namely, routine work and research work. In England many people employ Chemists for routine work, but hardly anyone employs the Research Chemist, and this is the real reason we are being outstripped by our foreign competitors. At present our manufactures are carried out by processes often as old as the industry itself. Empiricism appears rampant, for no one has troubled to probe to the very foundations of such industrial processes. The Research Scientist's duty would be to investigate the whole process as it stood, work out the inter-relationship of each phase, and the effect of changing the order of procedure; in a word, he must expose the skeleton structure upon which the whole is built. He must study his raw materials, know every property of those materials, and above all he must determine the mobility of the processes, and how to vary the products. Once let the true research man gain an insight into the inner meaning of a process and we can anticipate improvement. The aim of the research man must be to see that his firm produces the best goods possible. He must always be on the look-out for methods of cheapening his process, and gaining the maximum yield of finished products. To many business men the employment of such a man may appear a luxury; almost a gamble! The few that have such men are only employing them for some specific object, and, maybe, will rest content when that object has been attained. Such an attitude is fatal. The Chemist feels unsettled, while if the problem is difficult of solution his employers, not realising the situation, may decide either that he is no use to them, or that Science has failed them, with the result that the man is discharged. A new man may be engaged who will have to cover the ground again; time is thus lost, dissatisfaction results, and perhaps the manufacturer abandons his hope of obtaining scientific aid in disgust. I cite such an instance because I have actually seen several cases of this nature: cases in which, had the man been given more time, he would have succeeded in solving the problem. Unfortunately instances such as these are due in a large measure to the lack of appreciation by business men of the aims and endeavours of Science, and their lack of knowledge blinds them to the value of the work already done by the Chemist. Time is essential in preparing the scientific foundations upon which improvements and inventions will subsequently be built. Science never reaches finality, for to its adherents one discovery leads to another. True industrial research should be instigated in the same spirit, and research men should be treated as confidential servants of the company, secure in their situation, but realising that they are there to advance their employer's interests, and give him an adequate return for their salary.

Until more is done to clear away the barrier that prevents the commercial man comprehending the vast resources of Science, one cannot hope for an extensive employment of the research man. On the other hand, once let Industry realise the *modus operandi* of Science, and instigate research work, and we shall begin to advance upon sound lines.

The other type of Chemist that the works department would need is the routine man. Now, whilst grouping Chemists into two classes, I do not want it to be supposed that they and their training are distinct, and that one cannot merge into the other; rather is it the difference in their duties that needs description. In many works one man, provided that he displays the true scientific spirit, could play the double rôle, assuming the routine operations do not occupy his whole time and energy, although, for many reasons, it will always pay best to have a man devoting time solely to research, and to employ others upon the daily routine work. Only in cases where, for the time being, there are no apparent problems to be solved would I depend for investigations on the hybrid, but as soon as the need for exhaustive investigation arose, it would pay to turn him on to the research and to engage a man for routine. This brings us to an important point, and that is that not every Chemist is suited by temperament for research work as compared with routine. On the other hand, a man might be an excellent investigator but a poor routine Chemist.

The duties of the routine Chemist should be devoted to checking all materials supplied to the factory, and he should control the manufacturing processes by periodical tests. He should check every batch of finished articles, and keep them at one uniform standard, namely, the best possible. Naturally his work would bring him in daily contact with all works operations, and any anomalies or surprising results should be carefully noted and either looked into by himself or brought to the notice of the research department. He should become acquainted with all the other makes of goods on the market, and by analytical work be able, at least approximately, to tell what materials every rival firm is using. Whether or not his own firm could produce such goods at once would depend on several factors. If anything very new were met with that could not be made by their process, it would become the Research Chemist's duty to endeavour to devise means of producing the article. These few remarks may perhaps serve to show that the chemical staff should be concrete, the routine man helping the research man, and the research man devoting himself to any promising suggestions from the routine man. There should be neither discontinuity nor rivalry, either in the department or between the department and the rest of the firm's staff. How necessary such a system is can only be gauged by experience, for often the routine man comes across a need for investigation that has to be shelved through lack of time, but which, if it had been investigated by the whole-time efforts of the research man, would have led to money-saving improvements.

The above remarks with regard to the Research Chemist apply more particularly to chemical industries and to the industries directly depending upon chemical reactions, and naturally many firms would require a physicist, an engineer, a geologist, or a bacteriologist to conduct their research work. On the other hand, every firm should have their routine Chemist. Consider any firm, taken at random from the many different industries carried out in this country, and you will find they one and all consume a host of chemical substances, either in the form of raw materials or as accessary substances such as coal, lubricating oils, water, &c. The quality of these commodities varies greatly and cannot be determined by mere inspection. The Chemist can by analytical tests easily sort out the good from the bad. Thus by determining the calorific value, ash, volatile matter, &c., of a coal he can advise as to the selection of a specific coal likely to give the best return on the price paid for it. Lubricating oils are so easily doctored that a low-grade oil may appear a high-class article, whereas a few viscosity tests and tests of volatility, gumming, and so forth would discover this deception and save much wear and tear of plant. Boiler-feed water requires careful attention. Perhaps choice may be had of several sources, when only analysis can show which is the best. Then again in many localities there are solids dissolved in the water that lead to formation of scale in the boiler, and hence the consumption of more fuel to keep steam up.

The routine man would see that the water was "softened" by proper means and prevent this scaling, with all its attendant drawbacks of drawing off the boiler for cleaning and "chipping." Not only in these ways can a Chemist save his firm money by fuel economy, he can make frequent tests of the flue gases—that is, check the actual combustion of the fuel. What manufacturer has not at one time or another had a polite note informing him that at such and such a time his chimney was emitting black smoke. That smoke, whilst being obnoxious to the neighbourhood, is also detrimental to himself, for it represents so much unburnt fuel. The cause of this is either improper banking of the fires, unsuitable fuel for the type of boiler, or badly regulated air supply. The Chemist by analysis of the flue gases can determine whether or not the correct amount of air is being admitted, and his selection of fuel would naturally embody consideration of its suitability for the type of boiler-setting in use.

Every firm should see that their raw material is checked at delivery. Tanners, paintmakers and users, textile manufacturers, wool scourers, users of building materials, large emporiums and wholesale houses dealing in every type of commodity, even the small foundry and the large retail stores who do not check supplies, are at the tender mercies of the unscrupulous trader. It may be urged by many people that they cannot see their way to employing a Chemist. There are perhaps a few firms whom it would not pay to do so, but they should invoke the aid of the consulting Chemist, not spasmodically but as a matter of routine. In many factories little attention is paid to anything outside the actual production of a given article, and the managerial staff have only a limited knowledge of questions relating to fuel, lubrication, engineering, &c. In the nature of things this must often be the case, for the manufacturer is a business expert, not a Scientist. Yet he stands to lose money through lack of appreciation of the importance of subsidiary details. Let him continue to exercise the functions in his concern relating to actual business, but it will pay to have his factory under scientific control.

How much money is made by selling an

everyday article in the guise of a speciality with a nice name and done up in fancy wrappings cannot be stated in figures. Yet in every trade such articles are frequently encountered. Thus at a certain brewery the cleaning of the vats was effected regularly by means of a patent composition possessing a nice pink colour and a pleasant odour. The article performed its work quite well, so the firm were quite satisfied to pay half-a-crown a gallon for it, and never bothered any more about it. One day, however, they enlisted the services of a Chemist, and naturally he began to analyse and investigate all materials in use. Our friend the vat-cleaner came under his notice. He found that it was a solution of caustic soda, dyed to colour and perfumed to taste, the value of the solution being about 1½d. per gallon!

Yet another example similar to the above is the case of a large firm that for twenty-five years had been paying sixpence a pound for a boiler-scale remover. The advent of a Chemist soon stopped this pleasant philanthropy on the part of his firm, for he saw no need to pay three times its value for pharmaceutical hydrochloric acid when the desired result could be attained at a cost of a pound or so a year by other methods. These examples are typical of hundreds of others. It is almost an everyday occurrence to find articles on the market that, whilst admirable for their specified purposes, are sold at prices out of all proportion to their cost of production. In saying this it must be understood that these articles do not embody the results of much endeavour to arrive at their composition; they simply show that someone has realised that a substance in common application can be utilised under fancy names to supply an alleged "long-felt want." The presence of a Chemist would soon put an end to this state of affairs, and save firms much money.

Space forbids my dwelling on the hundreds of ways in which a Chemist can save and make money (for his firm). Those of my readers who do not submit anything to analysis have only to go through their own factory and keep asking themselves the question, "Do I know what that is? Is it what I pay for?" They will find they cannot in many cases supply an answer; then let such people, out of curiosity, invoke scientific aid, and judge by results. I only wish it were possible to get scientific experts in the various trades to converse with the manufacturers through, say, the local chambers of commerce, and perhaps then the latter would see a new aspect of affairs. Assuming that our manufacturers wish to enlist to a greater degree the Scientist's services, I am afraid that as things are it would not be possible to supply a very big demand for technical men. True, we have the men, but much remains to be done before they become truly efficient. Let us see what sort of a man we want and what training he must undergo.

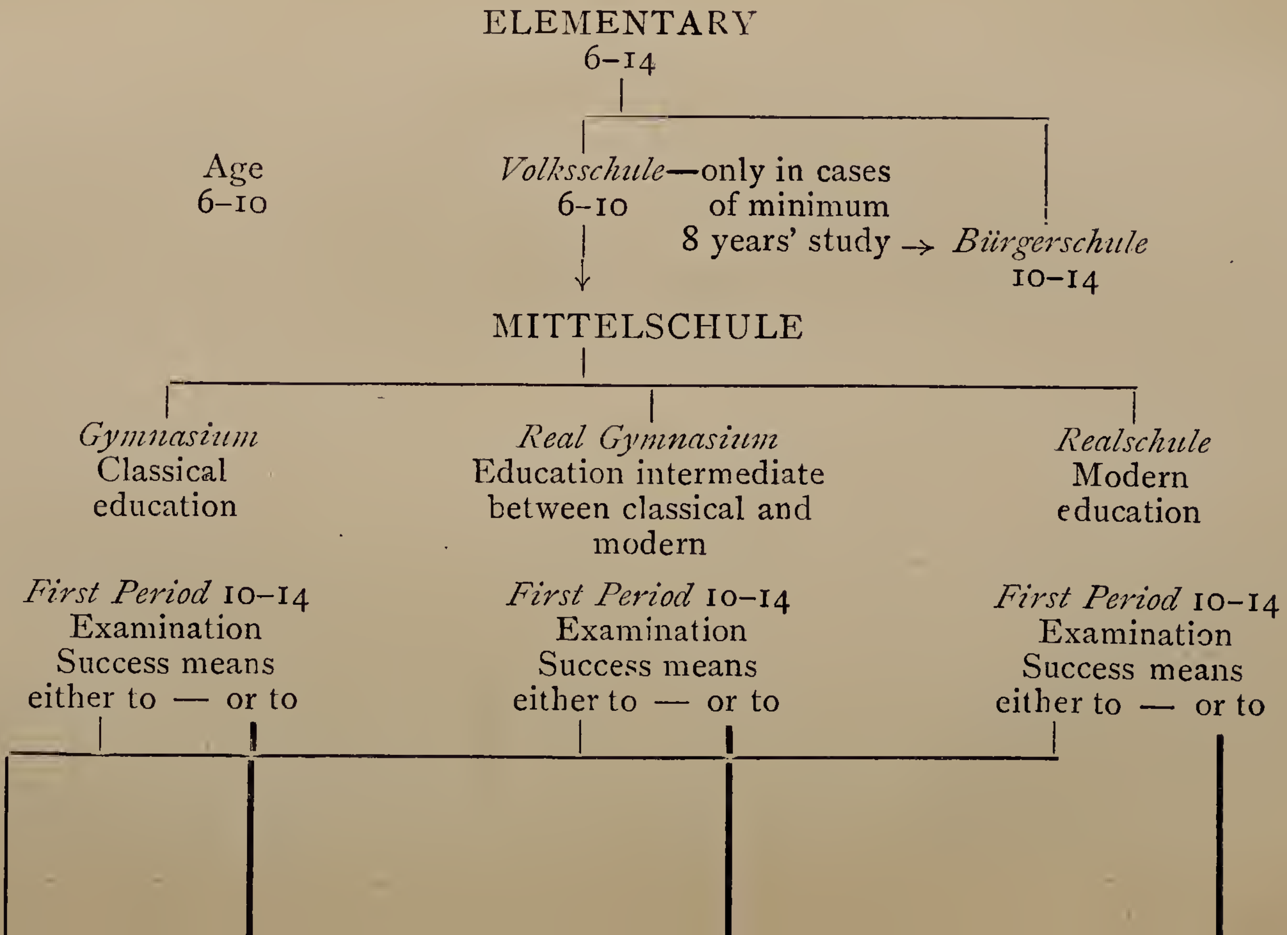
CHAPTER V

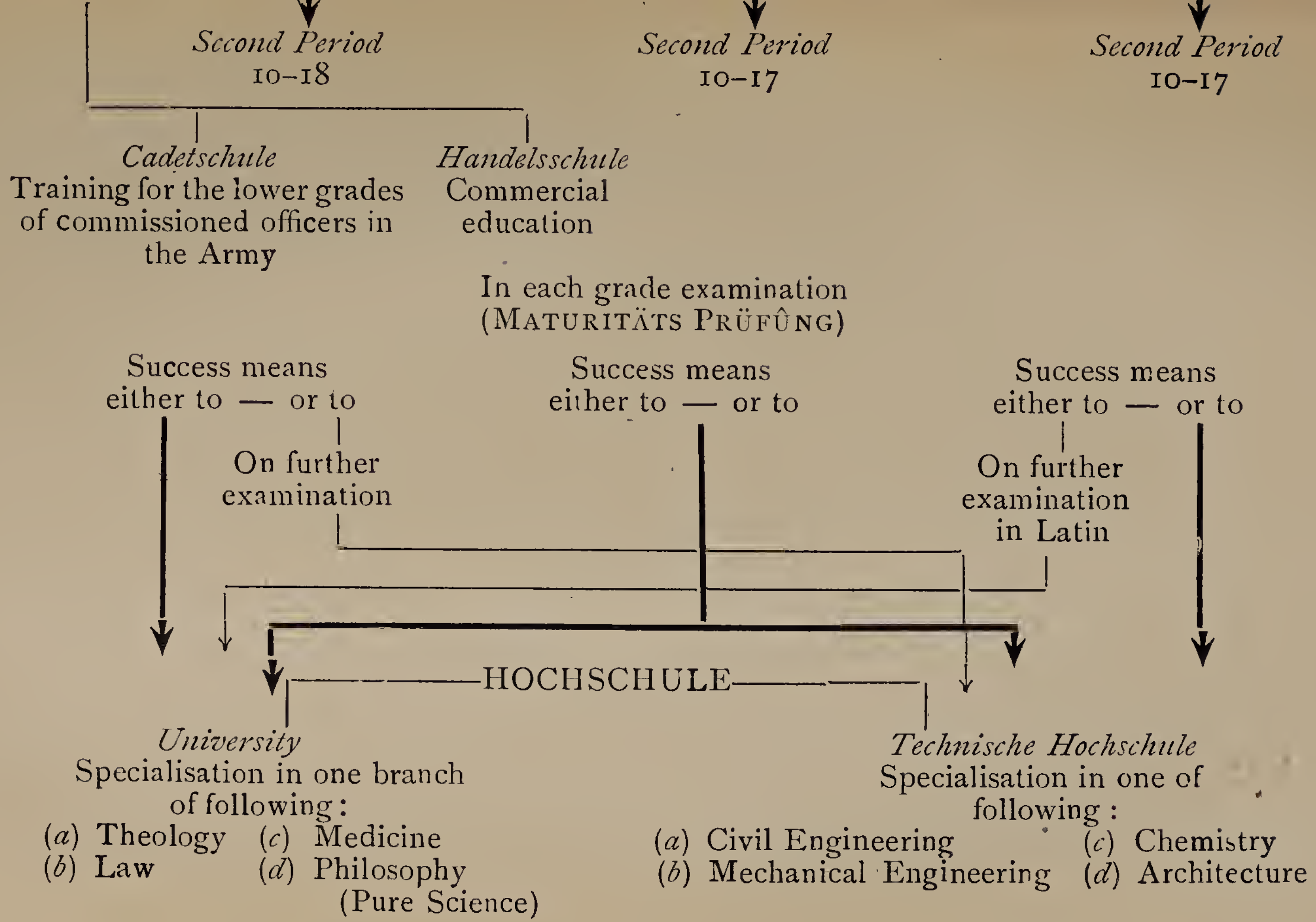
THE problem of the training of men for a commercial career is naturally closely bound up with our educational policy. There is no doubt our present system needs amendment, with particular stress laid on the co-ordination of the various grades now in existence. Under present conditions each grade is in theory a precursor to the next, whilst in practice there is no great evidence that any particular grade feels it is either a step to the next or a continuation of the one below. What we want is a working system linking up each grade, and the teachers in every grade encouraged, by results, to realise that they are all part of a huge process of developing the nation's brains to their highest degree.

The system of education in Austria is a grand example of the type we should aim at, and I feel sure the following brief account of its general outline will bring home to my readers the great need for altering the present system of education in England.

The aim of the Austrian people is to train

DIAGRAM OF AUSTRIAN SYSTEM OF EDUCATION




Second Period
10–18
Second Period
10–17
Second Period
10–17
Cadetschule
Training for the lower grades of commissioned officers in the Army
Handelsschule
Commercial education
In each grade examination (MATURITÄTS PRÜFÛNG)
Success means either to — or to
On further examination
Success means either to — or to
Success means either to — or to
On further examination in Latin
HOCHSCHULE
University
Specialisation in one branch of following:
(*a*) Theology
(*b*) Law
(*c*) Medicine
(*d*) Philosophy (Pure Science)
Technische Hochschule
Specialisation in one of following:
(*a*) Civil Engineering
(*b*) Mechanical Engineering
(*c*) Chemistry
(*d*) Architecture

their youths to their highest capacity, for they realise how essential it is for national progress to develop and cultivate powers of independent thought. In Austria every child, irrespective of birth, is compelled to go through a minimum course of education, and whether or not they proceed further with their studies depends on their own capabilities and the attitude of their parents. The minimum course prescribed covers eight years (from the age of six to that of fourteen). The first four years of this course is common to the whole system of education, and is carried on in the " Volksschule." When the pupil has completed this initial course of study, the parents are called upon to decide if they wish their child to proceed further than the minimum eight years' course. If they decide upon the latter the pupil proceeds to the " Bürgerschule " and completes the minimum training by attending at this type of school for the remaining four years. Should, however, the parents decide to let their child aim at a higher education, then the pupil on leaving the " Volksschule " proceeds to one or other of the three types of school embraced by the name " Mittelschule," or schools for what we call Secondary Education. The three types of school in this division are the " Gymnasia," "Real Gymnasia," and the "Realschule," each designed to meet specific requirements, but of course catering, in the early years of study, for the general school subjects. The "Gymnasia" are designed to develop classical education, and hence they specialise in Latin, Greek, &c., and pure mathematics, but not in Science. The opposite type of training to this, *i.e.* a "modern" education, is catered for by the "Realschule," in which the special subjects are modern languages, mathematics, and Science, but no Latin or Greek. The third type of school, the "Real Gymnasium," is a later addition to the system, designed to meet the demand for an education intermediate in nature between the extreme types. This school is characterised by the teaching of Latin but not Greek, and of Science and modern languages. The course of study in the "Gymnasia" covers a period of eight years (ten to eighteen), whilst attendance in the other two types of school extends over seven years. Each type of school has a break, or rather a halting-place, at the end of the first four years. Thus the pupil when fourteen years old can, if the parents wish it, branch off and pursue a course of commercial training in the "Handelsschule," which is designed to fit him for an ordinary business career. Is not this organised training for business somewhat of a novelty to our ideas, and far preferable to our methods of letting the youth "pick something up" as he goes on? One often hears that the representatives of Continental houses are more wide-awake than those of English ones. Can one wonder at it? The Austrians, for example (under these conditions), will have far less difficulty in finding a man equipped with that knowledge of the language and the customs of a country that counts for so much in business. Another reason for this greater knowledge of the Continental representative is to be found in the fact that so many of their youths are sent to England, France, or Germany, as the case may be, for at least a year, and thus study foreign methods. Now to return to the Austrian "Mittelschule," the student who does not branch off at fourteen continues his studies along more specialised lines until on reaching the age of seventeen or eighteen, according to the type of school he is in, he has completed his general education. There is then before him the State examination called the "Maturitäts Prüfûng," success at which stamps him as worthy of still higher training, and permits of his passing on to the "Hochschule"—that is, the highest division of education in Austria and on the Continent.

Moreover, should his parents' means be small, he is granted a scholarship to maintain him during his studies. In this phase of the question it must be borne in mind that the Austrian education is under direct State control, and the equivalent of our educational rate is with them more in the nature of a national tax—a tax just as necessary for the prosperity and protection of any country as those devoted to naval and military objects. The Austrian "Hochschule," or highest division of education, embraces two types of institution, namely, the University and the "Technische Hochschule." The University is divided into four faculties: (*a*) Theology, (*b*) Law, (*c*) Medicine, (*d*) Philosophy. The last-mentioned faculty embraces any branch of Pure Science, for the function of the University is to teach pure subjects or arts, in contrast to technical or Applied Science. These technical subjects are dealt with in the "Technischen Hochschulen," which also comprise four faculties, namely, (*a*) Civil Engineering, (*b*) Mechanical and Electrical Engineering, (*c*) Chemistry, (*d*) Architecture.

The student possessed of the "Maturitäts Prüfûng" can in general enter either of these types of institution, and in addition any particular one he chooses, but there are certain reservations. It was pointed out that the "Gymnasia" give a classical education, and hence their students are designed to enter the University, but should they wish to change over to the technical side they can do so by passing examinations in certain additional subjects. The same is true of "Realschule" students, who can at once proceed to the "Technische Hochschule" on obtaining the "Maturitäts Prüfûng," but must pass in Latin if they wish to change over to the University. In the case of students qualified in the "Real Gymnasia," which, as pointed out above, give an education of a nature between classical and modern, they can proceed without any additional subjects to either type of "Hochschule." The courses in the "Hochschule" cover four or five years, during which period the student devotes himself to one particular faculty, and at the age of twenty-one or twenty-two emerges fully qualified in either Pure Science, arts, or technical subjects. One point characteristic of this division of the "Hochschule" is that all the teachers for the schools are drawn from the University or "Technische Hochschule," whilst the army of technologists expanding and controlling the Austrian industries is recruited from the "Technischen Hochschulen." This brief and bald account of the

Austrian system, which is represented on pp. 56 and 57 in diagrammatic form, cannot but show the definite aim of the scheme, namely, to train for efficiency either in Pure or Applied Science, &c., and, moreover, to keep this aim in view throughout the whole period of study. Let us look at our own system in England, and briefly survey it while bearing this Austrian system in mind. The scheme now in existence in England may for our purpose be surveyed under three headings: introductory education, general education, specialised or higher education. The introductory education is carried on by the elementary schools *or* secondary schools *or* public schools. In this, the very commencement of our system, we have a case of overlapping and duplication of functions. There should be one grade, the elementary one, whose function is to ground the pupil in the three R's, and develop the natural curiosity of the child in such a manner as to enable it to *think for itself.* This grade should act as a trial ground in which the individuality of the pupil has a chance of being discovered, and then developed in succeeding grades. There should be no attempt to instil huge masses of indigestible facts into the mind of the pupil; the amassing of facts must come later. Nature study and simple experimental work must be the keynote, combined with smaller classes. Then, having prepared the youthful mind in this way, and given it suppleness and individual power of thinking for itself, we can look forward to a more thinking nation. As soon as the child has, so to speak, gained full benefit from this mental exercise it is fit to proceed to the secondary school, there to enter on the more serious amassing of knowledge. It is here its general education, *i.e.* the accumulation of facts, will commence, and with it the serious study of languages, literature, history, geography, mathematics, and elementary Science. This stage must not be regarded as a "cramming stage," to be judged by examination results, but must once again be an evolutionary process, imparting facts, developing individuality, powers of observation, and above all powers of deduction. Once more, it should be a trial ground for sorting out the pupils whom it will repay the nation to encourage financially and otherwise in continuing their studies in the next higher grade. Our endeavour should be to develop to their fullest extent the intellectual possibilities of our youths, giving everyone a sound general education, training their powers of thinking, and only letting those continue who show natural ability.

Having brought the pupil to the standard attainable in general education, he or she should now, if fitted for it, proceed to a higher institution and there begin to specialise.

The institutions we have for imparting instruction in the higher branches of learning vary greatly in their nature and scope. It is at this point that our present system becomes so involved and unwieldy, and overlapping becomes so rife. There are the Technical Schools and Colleges, University Colleges, and Universities of all degrees. There is no standardisation in their functions or results. Some people regard a Technical School as a substitute for the University, others regard it as a step on the way to the higher institution. Others again take no account of the Technical School. The net result is that both institutions perform much the same work, especially in the early part of their courses, and we have students needlessly repeating their work in their first year or so at the University.

The Technical School should be a precursor to the University, yet another trial ground; in fact, the final trial ground before we permit the student to be regarded as one fitted to be trained as an expert. These lines are not penned in belittlement of the Technical School, as the subsequent remarks will show. To-day we need these institutions for three main reasons, which show how much we need reform. The chief of these is that we need evening instruction in technical work, and the people who attend the classes are people engaged in industry, &c., during the day. The fact of such attendance shows that they have not been fully equipped for their posts, they have not been able, under our present economic and educational systems, to train to the full. Their attendance at classes after a hard day's work shows their willingness to study, but our manufacturers will not make it worth while for them to go the whole hog and become experts. This reveals the weakness of our present system ; the Technical School is to many a half-way house, there is no easy path from it to the University, that is, to out-and-out specialisation. Under the new order these institutions must have properly co-ordinated functions, and every institution must have a door leading to the University, open to all who have shown themselves fitted for downright specialisation. This brings us to the final stage in our educational scheme, the University.

The University should be a State University, the keystone to a great national organisation developed along lines indicated above. This

State University of necessity cannot be situated in one place, for it will incorporate all the existing Universities, such as those of Birmingham, Leeds, Liverpool, &c. The underlying principle will be to centralise the teaching of the pure science in divisional colleges, and localise the teaching of the applied subjects in the heart of the district wherein a particular industry is carried on. Thus we should have the teaching of the technology of textile manufactures situated at Leeds, Bradford, and Manchester. Birmingham, Sheffield, &c., would become seats of instruction in the metallurgy of steel and iron, and so on for every industry.

It should not be assumed from this that we should only find the manufacture of textiles taught, say, at Bradford, and that the chemistry, physics, engineering, and other departments should be converted to other uses. Far from it; the textile trade needs its chemists and its engineers, and under a proper regulated scheme the teaching in these subjects would bear directly on the trade concerned. The students at these classes would be men who had already climbed the educational ladder, and are now specialising, after receiving instruction in Pure Science at the Central University. There is a lot to be said for this scheme from an educational standpoint, while as a business scheme it will stand the closest scrutiny. Under its régime we should save thousands of pounds by prevention of the overlapping of expenditure on institutions. This saving would permit of getting real technologists on the staffs of the institutions, and the Pure Science teaching could be more thorough, whilst the technological training would likewise be more real.

There are people who may feel that there is no need to train men to such a pitch as outlined above, and that employers can get all they want by "bringing up" people on the works. "Fatal" is not the word to describe such a policy. Men are needed of the *highest* ability, training, and skill we can produce, devoting their energy to the expansion and maintenance of our commercial operations; men to investigate, to probe and prune our industries. The works-trained man can seldom develop into such a person, for the technologist requires all the knowledge he can get. Moreover, he wants the breadth of outlook, the "spirit of his science," and the power of original thinking that can only be attained in perfection by working and studying in the stimulating atmosphere of an academic institution. Remember that it is the academic man who is probing into Nature and causing her to reveal her secrets. We want the refined and searching methods of the academic man at the call of industry, to elucidate the hundred and one problems of everyday occurrence. Compared with the delicate methods of the man of academic attainment, works processes are crude and cumbersome. The youthful mind is readily influenced, and consequently the average works "trained" man comes to have a crude and rugged idea of his subject—in fact, only such knowledge as is contained within the four walls of one factory. As a man capable of thoroughly threshing out a problem he is useless compared with the individual possessed of University training. The man on a mountain-top can see far more than a man on a boulder at the foot thereof, provided it is not misty at the top. Our trained man is in the position of the man on the mountain; in front of him spreads the broad view of his subject, but we must see to it that his industrial view is not hampered by being solely academic. We want the widest academic view possible, but we want powers of applying it to industrial problems. The commercial man is prone to describe the academic man as unpractical. The latter may retort with equal force that the commercial man is not theoretical. People will argue about the relative importance of theory and practice, and dogmatically assert that one is of more importance than the other. They might as well argue which is the more important, the right or left side of the body. Together they constitute a homogeneous entity. Practice and theory are interwoven. In England from a commercial standpoint they are more or less asunder. We must link them firmly up in order to maintain and above all expand our industrial position. The link is the expert. In the future we must divert many of our University men into industrial channels, and spare no effort to train them to the highest pitch as technologists in its widest meaning. There is much to be done before this can be accomplished. Let us consider some of the main reasons for the present dearth of such men, and make some suggestions as to the lines upon which we can alter existing conditions in order to attain greater efficiency in the future.

CHAPTER VI

THE results accruing from the money and energy that we spend upon education are meagre in comparison with the return that might be got from a scheme which would make proper use of the trained man. The number of trained men who enter a commercial walk in life is insignificant compared with the number that enter the teaching profession. The youth who leaves school and proceeds to the University, and spends there three or four years in studying chemistry, finds in general that there are few posts open to him. Moreover, he will find that works posts are conspicuous by their rarity. The result is that he will become, willy-nilly, a teacher. In this capacity he retails the more elementary portion of his knowledge to the rising generation. Some of his pupils become interested in his science and decide to devote themselves to it. In course of time they, too, go to the University, spend three or four years studying, and—once again, in the majority of cases—they, too, become teachers. What a wasteful cycle, one generation becoming teachers of the next, without rhyme, reason, or regard as to their suitability. In similar cases on the Continent we should find that a large number of these men would have been absorbed into commercial undertakings, there to devote their knowledge and energy to expand and perfect manufacturing processes and business enterprises. We Englishmen should see to it that such a condition of things may be brought about in this country. It would revolutionise our industries ; it would make education a real live force. How many students fight shy of specialising because they feel there is no call for such knowledge? The result of the institution of a system that allowed of the trained man entering into commercial work and having his worth recognised would be that many more would train, our average standard of knowledge would commence to reach a higher level, concurrent with this change our industries and the standard of their products, methods, &c., would improve. Education would become more real, more alive, because this commercial outlet would give it a very definite aim.

Our teachers would be able to become such from choice, not from necessity, and this enthusiasm and aptitude of the natural teacher would still further help forward this march of intelligence, training, and specialisation. Yet again, educational expenditure could be regarded from a business standpoint, giving its return in the added profits of industry due to the application of the Scientist to commercial walks in life. The teaching profession could be made more attractive by higher emoluments due to keener appreciation of its merits, and real technologists could be appointed on the staffs of colleges—men there from choice after having spent some years in commercial work. These men would mould the technologist from the pupil possessed of a full knowledge of Pure Science. This question of a proper utilisation of the trained Scientist is at the root of the whole matter; unless we solve it education will continue stunted, a few men will become technologists, but the wasteful cycle mentioned above will still go on. How are we to bring the new state of affairs about? In one way only.

Industry and Science must co-operate for the nation's good. It is up to the manufacturers to make the move. I say with all respect that the majority of manufacturers have no appreciation of the ways and methods of Science. There are many manufacturers in this country who have never tapped the vast stores of knowledge bearing directly on their particular industry. How many firms use the same process that was in vogue when they first devoted themselves to a certain industry, and how many of these people would find on reading their subject up that there had been a vast number of improvements since then. The commercial man cannot find time to devote to this side of the question, but if he employed a genuine Scientist his industry would through him be able to keep up to date. Many of our commercial men are awakening to the influence Applied Science is having on industry, but their full appreciation of the fact and their wholehearted support are needed before we can really run our manufactures on truly scientific lines. Firms in this country that make use of the Scientist on thorough lines are now reaping the reward. Yet it seems a general feeling among business people that to employ a Scientist is a sort of luxury. If a real genuine Scientist possessed of the qualities demanded for industrial work can be obtained, he would no longer be regarded as a luxury, but as a necessity. The argument may be urged that it is impossible to obtain such a man. Up to a certain point that is true; it is not always possible to find men who have made a special study of any one particular industry, and that is why I say it is for the manufacturers themselves to make the first move. They know very well that if there is a demand for a certain article a supply will be thereby created to meet the demand; also, they know that the reverse is true and that supply is useless without a demand. Under present conditions there is no genuine demand for the technologist. The previous chapter will give in broad outline some idea of the training needed in order to fit a person to become capable of originating and developing an industry to its full extent. Yet if a young man were to follow this out to its utmost he would find that in general when he had finished his training he would be—stranded!

It must be remembered that he must first attain his training in Pure Science and then strike out on his training in technology. This means he must become possessed of a general knowledge of chemical engineering, chemical plant, means of handling goods, and methods of grafting his Pure Science on to industrial problems. He must study and specialise. This specialisation can take place in so many ways, and what incentive is there for him to pursue such a course in technology when the chances are a hundred to one against him having the opportunity to utilise his knowledge in a commercial way? The consequence is that the majority of our Chemists stop short in their training at a certain stage, devote themselves to the Pure Science, and subsequently become teachers. This is the reason we have not an army of technologists. Industry offers too scanty a field for a Chemist. Speaking from a commercial standpoint, we do not realise the far-reaching effect that the multitudinous ramifications of Science are capable of producing in our industrial undertakings. Many people are content if they have a few tests carried out on rigid routine lines. In general these tests are done by a person who has grown up from boyhood in the works, and subsequently become familiar with the daily tests. Such work, we know, must be done, it is essential to economic working, and for much of it as carried on to-day the routine man suffices. But, and this is the point, there is a need, a crying need, for higher work. Our manufacturers fail to realise how much more efficiently this work could be carried out by men possessed of greater elasticity of mind and a broader outlook. They will not give credence to the fact that what to them may appear an unfortunate happening in the works operations, resulting in a spoiled batch, may be capable in the hands of the Scientist of easy solution, and result in a subsequent improvement in the process. We need the man *able to initiate*, *able to investigate*, able to develop, to be on guard in our works, ready at any moment to fasten on to anything not properly understood, and wrest from it its inner meaning. If only some people in charge of works had a slight inkling of the scientific meaning and knowledge attached to what to them may seem everyday processes governed by chance, they would be appalled. But they have not, and they will not hearken to the Scientist because he is, they say, "not practical." He has not had charge of their particular plant. Let them take a Scientist into their works; in six weeks he will be practical, for his training so moulds his outlook that he can readily imbibe the details of works processes. Science is not simply a collection of facts and formulæ, but a delicate network of principles, laws, and relationships. Many of our chemical industries had their birth in the laboratory, and have grown to what they are by the fostering care of the man possessed of theoretical knowledge combined with commercial aptitude. This is the point at which Science merges into Industry. It is the stage at which we need the influence of co-operation to allow of the passage of our scientifically trained youth into the technical expert. It can only be brought about by smoothing down the rugged ground of prejudice existing between college and works, and giving the student a chance to gain real first-hand commercial experience of costs and markets. There is no need for a revolutionary upheaval, for we can evolve a system from the existing conditions that will allow of our trained youth gradually entering commerce as a real genuine technologist. Let us consider some suggestions for hastening on a movement fraught with such national importance.

CHAPTER VII

ONE cannot, and does not, expect the commercial man suddenly to blossom out into a Scientist, for his activities as a business man are essential to industrial prosperity ; but as a business man one does expect him to consider without prejudice any proposition bearing upon his commercial activities. This question of Science and Industry is a genuine business proposition which under proper conditions is capable of yielding a handsome return, but these proper conditions can only be attained by commercial men realising what Science has done, is doing, and can do in the future.

There is a certain type of commercial man who considers the Scientist unpractical, and hence of no value in industry. Now it is true the man who has just finished his training has not actual works experience, but he possesses knowledge that centuries of works experience will never give him, and he only needs actual contact with the works processes and appliances to be able to interpret his knowledge on a commercial basis. Thus in the refining, say, of coal-tar products the principles he has imbibed from the study of liquid mixtures go to the very root of the industry on the large scale. There is this difference: in his training course he has used apparatus constructed of glass, fractionating columns of size to give him the best result possible in his work; he has been able to use as many receiving vessels as he likes, and perhaps made a greater number of intermediate products than would be possible in the works process. But what does it matter? The principles underlying fractionation are the same in the works and in the laboratory; the student only needs an opportunity to witness works processes, and by virtue of his training and of the elasticity of mind it gives him he can readily attain to an understanding of the works process. One phase of the question in which the manufacturer can do so much to help in the training of the technologist is by simply allowing the local institutions to visit his works and witness actual works operations. There are many public-spirited people who do this to-day, and one generally finds such people are reaping the benefit of having a Scientist in their employment. Others may object that such visits would lead to the disclosure of works secrets. I think not, for I have been on many such visits and have noticed there is no divulging of secrets. Now it must be borne in mind that the students do not come on such visits to learn the process—they know it already and all its underlying principles—they come there to see large-scale operations, and become familiar with the factory equivalent of the apparatus known to them in the college. These factory appliances have been evolved from the academic apparatus, and we want our students to attain to the same sequence of ideas that lead up to this evolution of works plant.

Another way in which factory and college can become more closely knit is by the college reciprocating for these works visits in assisting the manufacturer in the choice of his Chemists, and, if needs be, placing their academic laboratories at his disposal.

As everyone acquainted with scientific investigation is aware, occasions arise that call for elaborate apparatus and academic facilities not ordinarily to be found in works laboratories. The installation of such equipment would mean a heavy outlay for apparatus that might be rarely used. It is upon these and similar occasions that the college should assist the manufacturer and place their fully equipped laboratories at his disposal.

The University of Kansas has in operation a scheme of Bursaries in applied chemistry. These Bursaries, which are endowed by local manufacturers, are awarded to students who have graduated in pure chemistry, and are well grounded in the applied science. The student to whom one of these Bursaries has been awarded remains at the University, but is engaged upon the solution of some works problem for the manufacturer who is, so to speak subsidising him. The results of the investigation in question belong to the manufacturer, and in return for the solution of the problem the graduate is given a certain bonus and the opportunity to take up a post with the firm he has been working for. The work is carried out in the college, and the manufacturer is spared the expense connected with the installation of a laboratory equipped for research. His interests are protected by the Professor, who renders periodical reports upon the work. Such a scheme as this may appeal to many as being all that is needed to bind together our colleges and the factory, but I feel there are too many pitfalls for it to be of real lasting utility. In the first place it may lead many factories, should they adopt it, not to engage the chemist, but to send all cases of investigation to the college, and continue running their operations on the same old-fashioned lines, with the result that many happenings will escape investigation, and the day when the technologist will be in most of our factories controlling and developing the processes will be no nearer. A modified form of these Bursaries as mentioned above would lead to lasting results *only* when the factory actually has its chemical staff in the works and is utilising the college's facilities as an extra aid. It is essential that the factory should have its chemical staff on the spot ever on the alert to fasten on to every occurrence the reason of which is not clear. With a fuller appreciation of Science and experience of its working, our manufacturers as business men will realise the great value of the trained Scientist in developing, controlling, and operating commercial processes. They will realise that whilst they need the expert technologist to develop and expand, they also need the trained man to control the works. It would be to their benefit if every one of their workmen were possessed of a certain amount of training other than that gained in the works. The man to control the operations will evolve from the conditions under which we train the expert, for it should be remembered that in the scheme of education outlined in Chapter V we cannot ticket a certain student for research or routine work and force him into it. Let us return to the question of the foremen, &c., possessed of training and understanding, and from this point of view consider how we can build up a more efficient army of controllers of operations. The foundation from which we start is the evening student.

The majority of students attending evening classes in the technical schools are youths who are engaged during the day in industrial occupations. The very fact that they sacrifice their evenings in order to make themselves more fitted for their commercial work is evidence that they realise the value of Science but that unfortunately their early training has been cut short. Do our manufacturers make full use of this type of employé, and do they encourage such people to continue their studies by utilising the knowledge they have already attained? In many cases the answer is in the negative, but there are some of these evening students who get a chance to rise because of their knowledge. The evening men under consideration are those who have spent four or five sessions in the classes, first studying pure chemistry and allied subjects, and subsequently attending classes in the technology of their particular industry. The man who has only attended one session in the technology of his subject is out of consideration here, but unfortunately some people have in the past regarded him as a trained man, and through his shortcomings have decided that Science was of no use to them. The type of evening man the manufacturer must encourage is the four or five session student who has gained considerable knowledge at much hardship to himself. Once let our manufacturers realise the value such a man has, and they in all fairness will remove this great hardship, for there is a limit to the period over which the brain remains supple, active, and retentive. I know of men who commence their day's work at six in the morning, stop at five at night, and then attend classes from seven till ten in the evening. It is beyond human power to gain the maximum benefit from their studies, it is not fair to let them continue under such conditions. That they are men of ambition and energy is shown by this attendance at evening classes, and hence they should be encouraged by having time allowed off during the day. This would be to the manufacturers' advantage, because they would then be getting a more efficient man in their works. We need a modified revival of the apprenticeship system, allowing off time for study. A scheme such as is in operation in our dockyards could be brought into vogue. The apprentices in our dockyards are allowed a certain term of attendance at the dockyard school. Every apprentice has this minimum training in his early days, but there is the opportunity for those of ability and perseverance to continue this school attendance in succeeding years. Continuation is only allowed to those who show that they have benefited by the prescribed minimum, and their continuation is determined from year to year by their past record. The attendance at school takes place mainly during dockyard hours. Efficiency is a bar to "malingering," for immediately a student loses interest in his studies his schooling ceases, and he spends his time in the shops. The results attained by such a scheme are sufficient guarantee of its value. In the engineering world former dockyards apprentices are to be found in high places, and practically every year the National Scholarships and Whitworth Scholarships and

Exhibitions are carried off by these men. Several large firms in this country have such a scheme in practice, but they are very few by comparison. The majority of such firms allow their apprentices certain afternoons off in order to attend classes at technical schools, the continuance of this privilege being determined by the progress of the youth. This type of scheme needs wide extension and amplification, so that in course of time evening schools may cease to exist as such, for the work will be done in the day. Evening work could then be of the nature of extension lectures delivered to men possessed of a good general knowledge, and hence the lecturer would be able to deal with the higher branches of Pure Science and Technology, and the lectures be of the nature of those courses of University Extension Lectures now delivered in various centres by experts attached to the Universities. There would also result from this apprenticeship scheme a wider and more useful sphere for our day technical schools. If commercial men would only try to test the utility of the trained man by adopting some such scheme in their factories, they would realise the value of this type of man to them in the routine of factory management. When in addition they realise the value of the technologist as adviser and director of operations, we can hope to see in England a system of education similar in general outline to that now in vogue in Austria and elsewhere on the Continent.

CONCLUSION

THE foregoing pages contain an honest attempt to view the question of Science and Industry from an impartial standpoint. They were written because I feel that we in this country are falling behind in utilising Applied Chemistry. Other countries are ahead of us, they have realised the value of the Chemist to Industry. Applied Chemistry in their hands has become, and will become still more so in the future, a mighty weapon of attack upon our markets. Competition in every walk of commerce becomes keener year by year. Efficiency will be the deciding factor in the stability of nations. The future Great Powers will not be those who possess the largest navies and armies, but those who possess the greatest number of trained intellects. The whole conditions of life, individually, nationally, and internationally, are slowly changing. Our present eminence in international affairs has arisen from our great national asset of a home coal supply combined with our English temperament. No doubt in the past we turned to commerce and became the pioneers therein, because we were the first nation to outgrow the resources of our country and to require food supplies from elsewhere. We had to expand, and our desire for expansion culminated in the British Empire, an Empire mapped out by the pluck and bravery of our soldiers and sailors, consolidated into a whole by our statesmen, but held together and maintained by our energies in commerce. Its integrity depends upon our commercial prosperity. When our industries had their birth Science was yet an infant, Industry could not invoke its aid. To-day Science is healthy, strong, supple, and pliant. Its aid is invoked by other countries bent on expansion; it has yielded up to them rich secrets and shown directions of expansion. As a nation we must employ it for our own benefit, to strengthen our present industries and build up new ones. Upon our manufacturers depends our prosperity; they it is who determine the manipulations of Industry. Upon them depends whether or not we utilise this mighty weapon of Applied Science to its full extent. We can train chemists equal to those of any other nation. We are not doing this as we should, for Science and Industry are not working in full sympathy. Our educational institutions are ready to do their part, they want the manufacturer and the employer to join forces with them, they want their help to help the nation. The question should be discussed from both standpoints. Realise what our rivals in trade are doing. Approach this great question in that broad-minded manner characteristic of this nation's business reputation. Then, when after mature deliberation and by experience it is found that Science can help in manifold ways, hold out the hand of Industry and grip that of Science. Let the clasp seal the compact to work in sympathy. Tackle the required innovations along business lines. Then we shall have the mighty forces of Industry, Science, and Education moving forward shoulder to shoulder for the mutual benefit, welfare, and prosperity of the nation.

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